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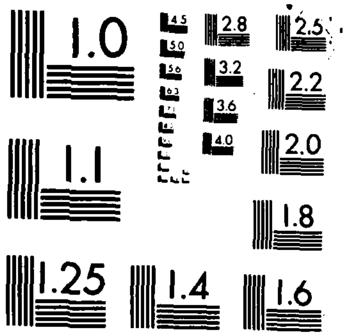

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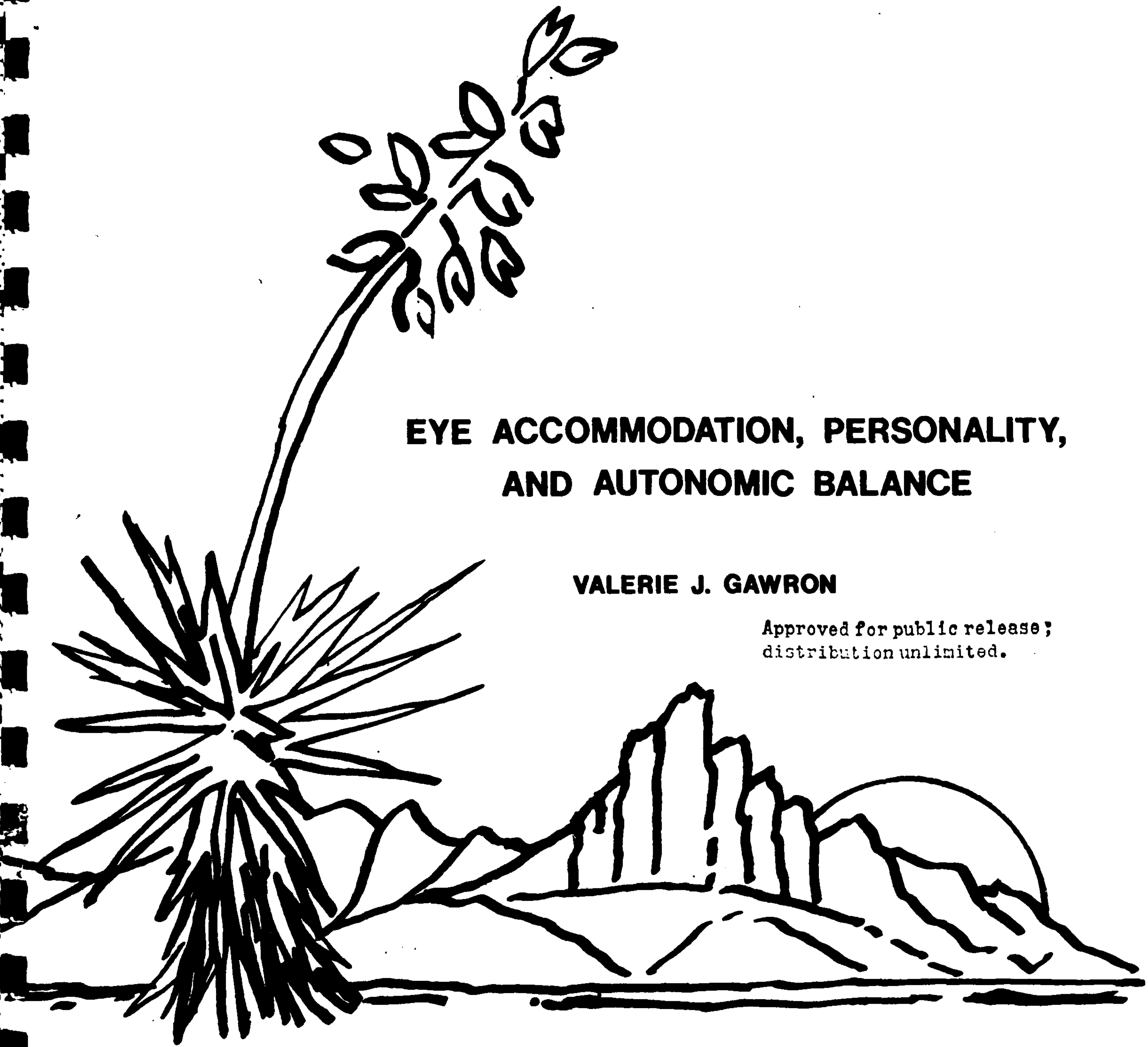

EYE ACCOMMODATION, PERSONALITY, AND AUTONOMIC BALANCE

VALERIE J. GAWRON

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Valerie J. Gawron

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THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system (ANS) governs the predominantly involuntary visceral actions of the body. Its two major divisions, the sympathetic (SNS) and the parasympathetic (PNS), differ in structure, transmitter substance, and function, as shown in Table 1. Neither system is consistently excitatory or inhibitory overall, but in every case the SNS and the PNS are mutually antagonistic in their influences on organs of the body. Also, although major SNS activation occurs during emergency "fight or flight" situations, the SNS is active even during normal functioning (although to a decreased extent) to oppose PNS influence on bodily organs. This dual-innervation system is the basic homeostatic mechanism of the body and regulates practically all smooth muscles and glands.

Dual-Innervation of the Eye

Eye accommodation. The lens, zonular fibers (the ligaments that hold the lens suspended in the eye), and the radial and circular fibers of the ciliary muscle (a smooth muscle within the eye) are the major mechanisms involved in accommodation (Brown, 1965). According to long-standing belief, in the relaxed eye the lens is stretched thin by tension on the zonular fibers and in this flattened condition has decreased dioptric power. These zonular fibers, however, are attached to the ciliary muscle. As the circular fibers of this muscle contract, the tension produced by the zonular fibers is opposed and this allows

Table 1

General Differences Between the SNS and the PNS

Structure	PNS	SNS
Origin	Brain stem and tail (craniosacral)	Spinal cord (thoracolumbar)
Ganglia distribution	Near organs they serve	Along spinal cord
Transmitter Substance		
Preganglionic	Acetylcholine	Acetylcholine
Postganglionic	Acetylcholine (cholinergic) (vago-insulin)	Adrenaline/noradrenaline (adrenergic) (sympathetic-adrenal)
Dispersion	To specific organs	Diffuse
Function		
General	Normal metabolism (anabolic)	Emergency situations (catabolic)
Specific examples:		
Iris	Constriction	Dilation
Heart rate	Deceleration	Acceleration
Bronchia	Constriction	Dilation

the lens to thicken and its dioptric power to increase. This "increase in the power of the eye associated with the thickening of the lens" is eye accommodation (Wald and Griffin, 1947, p.329). Conversely then, relaxation of the ciliary muscle results in increased tension on the lens and decreased dioptric power.

The contracting of the ciliary muscle and consequent thickening of the lens is called positive accommodation and serves to focus (on the retina) the images of objects close to the observer (Hurwitz, Davidowitz, Chin, and Breinin, 1972). Conversely, distant objects are brought into focus by negative accommodation or the relaxation of the ciliary muscle and the resultant flattening of the lens (Luckiesh and Moss, 1940). As with virtually all smooth muscles these antagonistic activities are mediated by the PNS and SNS. The processes of eye accommodation are summarized in Table 2.

Table 2

Summary of Eye Accommodation Mechanisms and Their Functions

	Positive Accommodation	Negative Accommodation
Focusing on:	Near objects	Far objects
Lens	Spherical	Relatively Flat
Zonular fibers	Relaxed	Tense
Ciliary muscle	Contracted	Relaxed
Relative speed	Slightly faster	Slightly slower
Dioptric power	Increased	Decreased

Although not totally invalidated by experimental findings from the current decade, this traditional conception of accommodation needs revision. With the establishment of the so-called "intermediate distance of dark focus" (Leibowitz and Owens, 1975), accommodation can no longer be represented as an active process in one direction only, namely, inward from a relaxed state at optical infinity. For the average dark focus to be maintained at an optical distance between one and two diopters (about arm's length) would require a relatively high steady innervation. Far more plausible is the alternative theory that the focal distance of the eye involves active dual innervation, inward (PNS) and outward (SNS) from its intermediate "relaxed" state.

Evidence supporting the dual-innervation hypothesis. Three major bodies of research form the basis of support for the dual-innervation hypothesis for the ciliary muscle. These are: anatomical stimulation and/or ablation of PNS and SNS nerves, direct instillation of cholinergic and adrenergic drugs into mammalian eyes, and measured accommodative responses during induced and/or extant stress conditions.

Anatomical studies. Morat and Doyon (1891, cited in Cogan, 1937) stimulated a cervical spinal nerve (part of the sympathetic trunk; such nerves are preganglionic to the superior, middle, or inferior cervical ganglia and serve to connect the spinal cord and the muscles in the head and neck) in cats and dogs and found a resultant flattening or negative accommodation of the lens. Similarly, Morgan, Olmsted, and Watrous (1940) stimulated this sympathetic nerve in four rabbits and found in each case that accommodation shifted outward from the resting position. When this nerve in a cat was severed, accommodation lapsed inward.

Mohney, Morgan, Olmsted, and Wagman (1942) replicated the 1-D shift outward during stimulation of cats, dogs, and rhesus monkeys. Olmsted and Morgan (1941) also found distinct flattening of the lens during sympathetic stimulation. Their subjects were rabbits and cats. Tornqvist (1966) concurs, and Toates (1972) also makes the positive accommodation-PNS, negative accommodation-SNS distinction, and Morgan (1946, p.101) states that "stimulation of the sympathetic nervous system in man, dog, monkey, cat, and rabbit causes a decrease in the total refractive power of the eye while stimulation of the parasympathetic causes an increase in the refractive power."

The evidence from these animal studies was so great that Olmsted (1944, pp.795-796) wrote, "In the past five years we have refracted the eyes of several hundred animals ... and have never found an exception to the rule that stimulation of the cervical sympathetic causes a change in the direction of hypermetropia [negative accommodation] .... Stimulation of the oculomotor nerve, on the other hand, produces a state of myopia." Finally, Schober (1954, p.4) reports that Horner's disease - "the loss of sympathetic ganglion in the neck - produces ... an extreme difficulty in accommodating for distance." And lesions of the SNS in humans increase dioptric power. Cogan (1937) cites a case in which removal of a portion of the SNS in a human patient resulted in an inward shift in accommodation from preoperative 6.5-D to 7-D for the right eye and 8.5-D for the left eye postoperatively.

<u>Drug studies.</u> Instillation of epinephrine hydrochloride, a sympathomimetic drug into the human eye causes decreased amplitude of accommodation (Biggs, Alpern, and Bennett, 1959) as do parasympatholytic

drugs (Eskridge, 1972, homatropine [synthetic atropine] into the human eye; Pitts, 1968, atropine [binds to one type of acetylcholine receptor] into cat eyes). Alpern (1958) found that homatropine also reliably reduces the variance of the refractive state. Conversely, parasympathomimetic drugs increase the amplitude of accommodation (Eskridge, 1972, eserine [competively inhibits acetylcholinesterase] into the human eye).

The SNS has two major divisions: alpha and beta. These refer to two types of adrenergic receptors. Alpha receptors are excitatory and control such activities as vasoconstriction and pupil dilation. Beta receptors, conversely, are inhibitory and control relaxation of smooth muscles. These subsystems are defined pharmacologically since no apparent structural difference exists. Adrenaline excites both types of receptors while noradrenaline excites alpha receptors alone (Davson and Segal, 1975). Hurwitz, Davidowitz, Chin, and Breinin (1972) have refined the SNS-negative accommodation theory and argue that it is the beta subsystem of the SNS that controls negative accommodation.

Hurwitz and his associates found that subdural instillation of isoproterenol (a beta-SNS stimulant; agonist for beta-adrenergic receptors) depressed accommodative response in vervets while propranol (a beta-SNS inhibitor; inhibits hyperpolarization of nerves) prevented such a depression. However, Hurwitz, Davidowitz, Pachter, and Breinin (1972), using the same method, found that levarterenol (norepinephrine, an alpha-SNS stimulant) also depressed accommodation. But they argue that this depression was mediated through beta receptor sites since a beta-SNS antagonist (propranol) inhibited this depression while an

alpha-SNS inhibitor (phentolamine; competitive alpha adrenergic blockade) did not.

Psychological stress studies. Early work in this area was done by Olmsted and Morgan (1939). They systematically submitted rabbits to several stressors: sudden taps on the nose, head shoving, jostling, and noise. They report an average increase of 1-D towards hypermetropia from resting accommodation. Morgan and Olmsted in that same year exposed human subjects to electric shock and noise. They also found an outward shift from resting position and conclude that this lens change is part of the sympathetic syndrome. Olmsted (1944) also reports the hypermetropic (outward) shift of accommodation during stress but states that this shift was momentary.

However, Westheimer (1957) verbally insulted two subjects to the point of anger and found an inward shift in accommodation. The increase lasted several minutes and in one subject the shift exceeded 1-D. Similar findings are reported by Leibowitz (1975). The accommodation of a shop technician who recently had been in an argument shifted from +1.5-D to +2.5-D. Anxiety also has an effect. A doctoral candidate's dark focus (resting level of accommodation) was monitored prior to and after his thesis-defense day. As the day neared, the candidate's resting accommodation shifted inward and returned to normal only after the defense day was past. Costello (1974) manipulated subjects' levels of stress by putting them through a progressive-relaxation procedure (no stress condition) and also by exposing them to slides of automobile accidents (high stress condition). She found small (.25-D to .26-D) but reliable shifts inward for stress and outward for relaxation.

These contradictory findings may be explained in terms of the duration of the stress response. Acute or startle responses such as those reported by Olmsted and Morgan (1939), Morgan and Olmsted (1939), and Olmsted (1944) reflect SNS activation while prolonged anger (Westheimer, 1957; Leibowitz, 1976) or chronic anxiety (Costello, 1974; Leibowitz, 1976) are PNS mediated. This coincides with Porges's (1976) "Two-Component Model of Attention." According to this model, stimulation results in three responses in an organism. The first is an immediate response akin to the orienting reflex. It is PNS mediated and occurs within one second of stimulation. This is followed by a short-latency response of four to five seconds that is characterized by SNS excitation or PNS inhibition. It may be this response that results in the hyperopic shift reported by Olmsted and Morgan (1939), Morgan and Olmsted (1939), and Olmsted (1944). These two responses define the reactive component of attention.

The third response reflects the sustained component of attention. It occurs subsequent to the two reactive responses and is characterized by reduced heart rate variability and inhibition of motor and respiratory activity. It, therefore, reflects a general PNS response. This sustained response may have resulted in the inward shifts of accommodation reported by Costello (1974), Leibowitz (1976), and Westneimer (1957) occurring during prolonged heightened emotional states.

The two-component model was supported in a study with hyperactive children reported by Porges, Walter, Korb, and Sprague (1975). They found a biphasic heart rate response of deceleration and then

acceleration immediately following the start of a reaction-time task. This is consistent with the immediate PNS (deceleration) and short-latency SNS (acceleration) responses of the reactive phase. A sustained PNS (deceleration) response occurred for children under medication. Cheung and Porges (1976) report similar findings with normal adult males. The short-latency reactive SNS response and the sustained PNS response also occur after electric shock and are associated with central nervous system action, "transient catecholamine (dopamine and norepinephrine) action followed by a cholinergic rebound together with subsequent decreased catecholamine activity" (Anisman, 1975, p.463).

Alternatively, the PNS- and SNS-accommodative responses may be differentiated by the type of emotion the subjects were experiencing. The hyperopic shifts reported by Morgan and Olmsted (1939), Olmsted and Morgan (1939), and Olmsted (1944) all resulted after presentation of abrupt, unexpected, noxious stimuli. The emotion these stressors aroused might be classified as fear. In the studies reporting myopic shifts, subjects viewed automobile accidents (Costello, 1974), and a doctoral candidate defended his dissertation (Leibowitz, 1975). Both of these would seem to elicit anxiety. Finally, Westheimer's (1957) subjects and Leibowitz's (1975) shop technician were angry.

Gellhorn (1953) in a review of research concerning the physiological responses associated with different emotions, concluded that "fear causes reactions predominantly sympathetic, and feelings of hostility and anxiety predominantly parasympathetic discharges" (pp.337-338). This alternative hypothesis does not necessarily

contradict the acute - chronic differentiation of PNS and SNS responses since fear is usually transitory while anxiety and anger are relatively prolonged. For example, Miller (1978a, 1978b) correlated the state of dark focus, or resting accommodation, over a three-week period with the subjects' self-rated moods. The resulting correlations were not high, but the greater the variability of subjects' resting accommodation, the more likely that this was related to mood changes.

Finally, Ong and Fisher (1973) asked subjects to read 20/50 acuity-level paragraphs while wearing varying strength accommodative lenses (-2 to +2 D). They found that the mean amplitude of GSRs linearly increased as accommodative power of the lenses changed from -2 to +2 D. This may be due to the sympathetic compensation for the increased dioptric lenses or to the aversiveness of such a situation. In conclusion, Leibowitz and Owens (1975) state that variations in accommodation "would reflect the balance between sympathetic and parasympathetic activation" (p.548).

Visual Abnormalities

In the normal, emmetropic eye, parallel rays of light are refracted and then received exactly at focus on the fovea - the result is a clear, sharp image. There are two visual abnormalities that cause the image to be out of focus: hypermetropia (hyperopia) and myopia. In the hypermetropic or far-sighted eye, the parallel rays of light remain unconverged when they reach the fovea, and so the image is blurred. Conversely, in the myopic or near-sighted eye, parallel rays of light converge in the vitreous humor before they reach the fovea, again

resulting in an out of focus image (Thorington, 1904). Hypermetropia and myopia may be viewed as deficits in positive and negative accommodation, respectively.

The linking of visual abnormalities, especially myopia, with personality characteristics seems to have begun with Thorington (1904). By casual observation based on years of clinical experience, he stated that the "myopic child at school soon ranks high in the class, is fond of study, of books, music, or needlework, according to the sex. The myope, in other words, is usually literary in taste. Myopes avoid out-of-door sports ... " (p.118). Butler (1929) also from clinical observation states that myopes are introspective and "bad mixers."

Rice (1930, cited in Trevor-Roper, 1970) provides an expanded description of myopes:

> A near-sighted child ... is not dependent on others for entertainment and is liable to grow rather contemptuous of the abilities of others. He does not adapt himself to the surroundings and is not willing to make compromises. He is often severe in his righteousness and his rightness and may become a disagreeable personage (pp.14-15).

and hypermetropes:

> ... nearly always a jolly good fellow ... he has a ravenous appetite because of his activity, he scarcely knows fatigue.... He is tanned, masculine, very aggressive and is likely to be a devil with women (pp.15-16).

Gesell, Ilg, and Bullis (1949) describe the myope as having a precocious interest in books, overconcentrating on near activities, being introjective and demanding and having difficulties in making transitions. From these descriptions a pattern seems to emerge of the introverted myope and the extraverted hypermetrope. Lanyon and Giddings

(1974) in a review of this research conclude that "it has been rather consistently shown that myopes tend to be, in comparison to nonmyopes, somewhat more introverted, overcontrolled, and tolerant of anxiety" (p.279). Empirical research seems to confirm this contention. Mull (1948) found a slight tendency for myopes to score higher than emmetropes on the introversion scale of the Bernreuter Personality Inventory. Similarly, Beedle (1974, cited in Young, Singer, and Foster, 1975) and Beedle and Young (1976) found a tendency for myopes to be more introverted than hypermetropes as measured by the Omnibus Personality Inventory.

Using the Rorschach, Van Alpern (1952, cited in Young, Singer, and Foster, 1975, p.680) concluded that myopes have "less concern about the outside world, increased thinking in abstractions, and increased focus of conscious thinking with better control over emotions." Morgan (1960) found a reliable positive correlation between myopic refractive error and bookishness - a characteristic associated with introversion. Young (1967) reported that myopes scored lower than nonmyopes in exhibitionism on the Edwards Personal Preference Schedule. Finally, Zeiger (1977) found that myopes viewed the world as noxious, irrational, and pressing on them - perhaps a cause of the introversion?

Randle (cited in Roscoe and Benel, 1978) states again from clinical impressions that myopes are inward-looking, defensive, and perseverative while hypermetropes are outgoing, flexible, and reactive to their environment. He classifies the former as parasympathetic and the latter as sympathetic types. This is seemingly an echo of the Leibowitz and Owens (1975, p.680) contention that variations in

accommodation "reflect the balance between sympathetic and parasympathetic activation."

Autonomic Balance

Individuals vary in the degree of response to stimulation but seem to remain individually consistent across situations (Duffy, 1957). This consistency is reflected in individually "specific response patterns in autonomic functions" (Hodges, 1976, p.185) and has led to the principle of relative response-specificity (Lacey and Lacey, 1958, p.50) which states that for a "given set of autonomic functions ... Ss tend to respond with an idiosyncratic pattern of autonomic activation in which maximal activation is shown by the same physiological function, whatever the stress."

Wenger's $\bar{A}$. In the early 1940s M. A. Wenger developed and validated a battery of physiological measures designed to position an individual along an SNS-PNS dominance continuum. His work was first reported in 1941 in an article that describes some 20 physiological measures taken from 62 children aged 6 to 11. A subsequent factor analysis (performed by Thurstone, no less) led Wenger to propose a general autonomic factor and a specific muscle factor. In the following year (1942b) he factor analyzed 80 physiological measures on the same children and again found an autonomic factor. There were 11 tests that loaded on the factor and each had dual SNS and PNS activation as shown in Table 3.

In 1943 Wenger and Ellington published their method for measurement of autonomic balance ($\bar{A}$). They had reduced the number of tests involved to seven and used the factor scores from the autonomic

Table 3

Wenger's Autonomic Factor

Test	PNS Dominant	SNS Dominant
Dermographia Latency	short	long
Dermographia Persistency	long	short
Salivary Output	high	low
Percent Solids in Saliva	low	high
Heart Rate	slow	fast
Sinus Arrhymia	much	little
Standing Palmar Skin Conductance	low	high
Non-palmar Skin Conductance	low	high
Respiration Rate	slow	fast
Systolic Blood Pressure	low	high
Increase in Systolic Blood Pressure during Repeated Measures	minimal	large

(adapted from Wenger, 1942b)

factor as weights to assign to an individual's scores on each test. The result was a single index, $\bar{A}$, for each subject placing him or her on the SNS (low scores) - PNS (high scores) dominance continuum. $\bar{A}$-scores formed a normal distribution across subjects (Wenger, 1957; Wenger, Engel, and Clemens, 1957) and for any one subject remained relatively constant over time (Wenger, 1942a, 1943; Wenger, Engel, and Clemens, 1957). For further description of the $\bar{A}$-battery, see the Methods section.

The Wenger battery has been criticized by Porges (personal communication, April 23, 1979) for the use of skin conductance as a

measure of SNS activity. Wenger (1942) stated that he would develop a battery based on the chemical differences between the SNS and PNS transmitters. Since the sweat glands, though controlled by the SNS, are cholinergically and not adrenergically innervated, measures of their activity are inappropriate in a battery that proposes to discriminate SNS and PNS activity on the basis of different transmitter substances. Porges has developed another measure of $\bar{A}$, C_w .

Porges's C_w . In 1976 Porges proposed a new approach in measuring autonomic functioning, an approach based on the close link between vagally mediated respiration and heart rate. During inspiration the stretch receptors in the lungs inhibit the vagal efferents to the heart. As a result, heart rate increases. Conversely during expiration, the vagal efferent to the heart increases and heart rate decreases. This periodic heart rate change is called respiratory-sinus arrhythmia and is, as Porges states (Porges, Bohrer, Keren, Cheung, Franks, and Drasgow, 1979, p.2), "related to vagal tone, since the accelerative peak occurs in the absence of a major vagal influence and the decelerative peak is in response to the addition of vagal efferent input to the heart."

A method was needed to measure the coincidence of respiratory and HR activity. Porges advocates cross spectral analysis with a resultant coherence statistic (a normalized function with values ranging between zero and one) to reflect the amount of covariance between the two physiological measures at each frequency in the spectrum:

$$C_w = \Sigma [C^2_{(\lambda)} F_{H(\lambda)}] / \Sigma F_{H(\lambda)}$$

where: C^2 is the shared variance of HR and respiration, and F_H is the

power density of HR at each frequency (lambda) at which respiration occurs. The product of these values is summed over the dominant frequencies of respiration. C_w is the proportion of shared variance between heart period and respiration. It "may provide a quantitative estimate of the brainstem mediation of the influence of stretch receptor activity on heart period activity" (Porges, et al., 1979, p.5) and so be a measure of central autonomic functioning. Conversely, the denominator of C_w reflects the amount of variance of the heart period process occurring within the respiratory frequency band and may be a measure of peripheral autonomic functioning.

Autonomic balance and personality. The development of the $\bar{A}$ battery allowed Wenger to test the relationship between personality and physiological balance. In 1947 he selected children with extreme scores of $\bar{A}$. He then examined multiple personality measures of the children: Child Behavior Rating Scales, School Rating Scales, and of their mothers: Bernreuter Scale during pregnancy, ratings of their home environment, and additional physiological measures. Wenger found PNS-dominant children had a more adequate diet, were more emotionally inhibited, patient, and neat but less active, emotionally excitable, suggestible, and fatigable. SNS-dominant children were the opposite and in addition had less domineering mothers and were from less child-centered and less coordinated homes.

Wenger (p.308) concluded:

> Predominance of sympathetic activity will be associated with and facilitative of emotional behavior, impatience, activity, fatigue, and related behavior. Predominance of parasympathetic activity will be found associated with and facilitative of stolidity, and a

> tendency to withdraw from the group or to dominate it when withdrawal is impossible or undesirable.

This relationship between nervous system activity and personality was reviewed by Eysenck and related to the introversion-extraversion continuum. This has produced a sizeable body of research.

The Eysenck Hypothesis

H. J. Eysenck (1955) introduced a theory of human behavior that blended Jungian personality traits with physiological concepts of cortical inhibition proposed by Pavlov and Hull. Eysenck (1958; 1967) extended Jung's personality theory by proposing that human behavior varies on two independent dimensions: neuroticism (emotionality, stability, ego-strength) as well as Jung's continuum of introversion - extraversion (outgoingness or sociableness of an individual). Eysenck then proposed that these behavioral differences reflected physiological differences in the speed and strength of production and dissipation of reactive inhibition as suggested by Pavlov.

Eysenck (1955, p.96) summarizes the Hullian concept of reactive inhibition:

> Whenever any stimulus-response is made in an organism (excitation), there also occurs simultaneously a reaction in the nervous structures mediating this connection which opposes its recurrence (inhibition).

Introverts "generate reactive inhibition slowly and dissipate it quickly, whereas extraverts generate reactive inhibition quickly and dissipate it slowly" (Heilizer, 1975, p.280). Although Eysenck has modified his theory over the years, the dimensions of introversion - extraversion and neuroticism and their relation to cortical inhibition

still remain key concepts in the theory (Eysenck, 1967; 1973).

Farley and Farley (1967, p.215) restate Eysenck's hypothesis that these physiological differences manifest themselves in behavioral differences:

> ... because of the hypothesized greater inhibitory potential of the extravert as compared to that of the introvert ... the extravert will seek arousal-producing stimuli so as to maintain some optimum level of 'arousal potential,' ... whereas introverts, with a hypothesized high excitatory potential, will attempt to avoid arousal-producing stimuli.

As related to $\bar{A}$, Eysenck (1953, p.198) argues for the view "that neuroticism is correlated with deviation from autonomic balance in either direction, while extraversion and introversion are related to the direction of the deviation from autonomic balance." "Those with apparent SNS dominance ... would be more extraverted, while those with apparent PNS dominance would be more introverted" (Sternbach, 1966, pp.39-40). It is further suggested that the relationship between autonomic balance and neuroticism is U-shaped such that individuals with extreme $\bar{A}$-scores in either direction also have high neuroticism scores (Schalling, 1975). Similarly, the individuals with extreme $\bar{A}$-scores will also have extreme introversion - extraversion scores but at either end of the continuum, again describing a U-shaped relationship. Tests of the Eysenck hypothesis have been both supporting and contradicting.

If extraverts have greater cortical inhibitory potential than introverts, this should be manifested by seeking behavioral stimulation to obtain an optimum level of arousal. Farley and Farley (1967) correlated extraversion scores from the Eysenck Personality Inventory with scores from a Sensation Seeking Scale and found a reliable positive

relationship (r = +.47). Extraverts should also be more tolerant of pain. Lynn and Eysenck (1961) report the correlation between extraversion (scores from the Maudsley Personality Inventory) and pain tolerance (endurance in seconds of heat stimulation) also to be positive and reliable (r +.69).

Extraverts should also do better than introverts on performance tests if the tests are performed under high activation. This activation would raise the extravert's lower level of arousal to near optimum while pushing the introvert's higher level beyond optimum. M. W. Eysenck found this to be the case for recall of paired associates (1975) and a prose passage (1976). However, Goh and Farley (1977) found that extraverts had <u>shorter</u> latencies than intoverts in an unstressed problem solving task.

The relationship of the Goh and Farley finding to the Eysenck hypothesis and the previously cited research is unclear; SNS-dominance may yield faster reaction times under any circumstances. Finally, Hogan (1966) found poorer vigilance (low arousal task) performance for extraverts than introverts and related this to the extraverts' lower (suboptimum) cortical arousal. Hastrup (1979) reports a similar finding for her difficult task condition (detecting a target stimulus of 56 dB with a 55 dB standard signal) but not for the easy task condition (57 dB target signal).

The hypothesized underarousal and SNS-dominance of extraverts should be physiologically demonstrable. Three physiological measures have been used in testing the Eysenck hypothesis:

The first is the occurrence of alpha rhythm in the EEG. As Gale, Coles, and Blaydon (1969, p.220) point out, "an inverse relationship between alpha amplitude and arousal (within the waking stage) is generally accepted." Therefore, extraverts should have higher alpha amplitudes. Savage (1964) reports exactly this and Gale, et al. (1969) conclude from examining a whole range of EEG frequencies that extraverts do seem to have a predominance of cortical inhibition. Similarly, Frigon (1976), after examining the mean duration of alpha blocking during extinction of a classically conditioned response, also concluded that introverts were more cortically aroused than extraverts. But Broadhurst and Glass (1969) found that introverted subjects had higher alpha amplitudes. Heart rate (HR) is another PNS - SNS discriminator. PNS-dominant individuals (introverts) should have low HR while SNS-dominant individuals should have high HR (Wenger, 1942b). Small (1974) directly examined this and found no supporting evidence.

Most of those examining the relationship between extraversion and SNS-dominance have used skin conductance (SC) as the measure of arousal. This Eysenck hypothesis was supported by Mangan and O'Gorman (1969) who found that extraverts had greater galvanic skin response to onset of a tone than introverts did. Fowles, Roberts, and Nagel (1977) found that SC levels increased during stress (performance of a difficult paired associates task) for extraverts while levels for introverts remained at baseline. But, Coles, Gale, and Kline (1971) report that those who score low on the EPI have more spontaneous SC activity than ambiverts and extraverts. Several researchers have not found a relationship between extraversion and SC (Burdick, 1966; Purohit, 1966; Revelle,

1974; Small, 1974, 1976).

Finally, McManis, McCarthy, and Koval (1978) found that hyperactive children are SNS dominant (salivate less than normal children when stimulated with lemon juice). Under the influence of the drug that counteracts the behavioral disorder, hyperactives were less extraverted. Finally, Hume (1968) measured the SC, digital pulse volume, HR, and EEG alpha for normals, neurotics, and psychotics. He found no consistent physiological correlate of extraversion but states that neuroticism was indeed related to autonomic activity such that neurotics had higher SC but lower cortical arousal that normals. And Lacey (1967) concluded that there are three complexes of arousal (autonomic, behavioral, and electrocortical) and that these may act independently and not synchronously as Eysenck's theory suggests.

In summary there is evidence for and against the Eysenck hypothesis and there have been attempts to reformulate or modify the theory (for example see Claridge, 1967). The issues, however, remain unsettled. Multiple measures of PNS/SNS balance are needed to provide a highly discriminating test. And so we have come full circle. Lanyon and Giddings (1974) conclude from a review of relevant research that myopes are introverted. Myopia is an inability to accommodate to far objects, a process mediated by the SNS. Could myopia be a deficit of the SNS and therefore a reflection of PNS dominance? Wenger (1947) states that PNS-dominant individuals are introverted, as are myopes. Coincidence, or are myopia and introversion results of a single underlying physiological imbalance?

METHOD

The links between physiology and the personality characteristics discussed herein are many, but the chain is twisted and, in places, broken. It was the purpose of this research to examine and test the shape and strength of the links. It was expected that measures of eye accommodation (EA) would be reliably related to $\bar{A}$ and C_w such that, the more myopic or the more introverted the individual, the higher (towards PNS dominance) his or her $\bar{A}$ and C_w would be. Similarly, the more myopic subjects would also be the more introverted. One further prediction was made on the basis of the Eysenck hypothesis, namely, that neuroticism would be positively correlated with deviation from the mean $\bar{A}$.

Eysenck Personality Inventory

The EPI is a minor revision of the earlier Maudsley Personality Inventory and provides three scores for each subject: extraversion, neuroticism, and transitivity/consistency of responses (lie-scale). The first two scores are hypothesized to be independent, and near-zero correlations have been found between them (Burdick, 1966, r = +.06; Harrison and McLaughlin, 1969, r = -.09). The lie-scale serves to identify capricious subjects, ones trying to conceal something, or ones with a basic reading problem.

The validity of the EPI has been demonstrated by reliable positive correlations of self-rated neuroticism with the neuroticism scale (Harrison and McLaughlin, 1969, r = +.56; Stones, 1977, r = +.47), self-rated extraversion with EPI extraversion scores (Harrison and

McLaughlin, 1969, _r_ = +.74; Stones, 1977, _r_ = +.57), peer-rated neuroticism with EPI neuroticism scores (Gibson, 1971, _r_ = +.44) and peer-rated extraversion with EPI extraversion scores (Gibson, 1971, _r_ = +.61). Similarly, self-rated extraverts' and introverts' EPI I/E scale scores were reliably different (Vingoe, 1966). Finally, Wakefield, Sasek, Brubaker, and Friedman (1976) correlated the I/E scale scores on the EPI and Myers-Briggs Type Indicator. The resulting correlation (_r_ = +.58) provides consensual validation.

Eysenck and Eysenck (1968) report test-retest reliabilities for the I/E and N scales over one year to be .88 and .84, respectively, and over nine months, .94 and .92. They also found split-half reliabilities of .36 for I/E and .89 for the neuroticism scale. Finally, Farley (1971) reports test-retest reliabilities for the extraversion and neuroticism scales to be high after four weeks, for males .78 and females .87 on each scale.

<u>Wenger's Autonomic Balance Index</u>

The $\bar{A}$-index is derived from a battery of seven physiological measures taken while subjects are resting. Its purpose is to derive a single estimate describing a pattern of physiological responses. Such patterns have been found to be consistent over situations (Schnore, 1959). The battery measures levels of physiological functioning rather than lability or range, and for HR and SC, such measures have been the most useful (Lazarus and Opton, 1966). The $\bar{A}$-index has been found to be both reliable and valid (Wenger, Engel, and Clemens, 1957). The

intercorrelation of $\bar{A}$-indices taken one year apart was .72 (Wenger, 1942a). The beta weights in the $\bar{A}$-index defining equation over a two-year period correlated from .92 to .98 (Wenger, 1943). Finally, Lajpat Rai (1978) reported an r = +.89 between Wenger's $\bar{A}$ regression equation and his own calculated from a sample of Indians. Subsequent retesting of 18 subjects one year later yielded a reliability coefficient of .75.

Wenger (1949) reported that antagonistic pairs of autonomimetic drugs produced reliable shifts in $\bar{A}$-scores: sympathomimetics lowered $\bar{A}$-scores, while parasympathomimetics raised the scores. Smith and Wenger (1965) measured $\bar{A}$-scores for 11 doctoral candidates prior to oral defense and one month before or after. They reported unanimously lower $\bar{A}$-scores on the thesis-defense day, a sympathetic response. Wenger and Cullen (1972) reported $\bar{A}$-scores for 24 mental patients; 23 of these, with anxiety disorders, had extremely low $\bar{A}$-scores. The 24th patient was hyperinsulinic and had an $\bar{A}$-score nearly six standard deviations above the nominal mean. Finally, McKelligott (1959, cited in Wenger and Cullen, 1972) found high $\bar{A}$-scores for patients with lesions in the cervical (SNS) nerves and low $\bar{A}$-scores for those with lumbar (PNS) lesions.

The conclusions of the last two studies are supported by Gellhorn's (1953) contention that autonomic imbalances are reflected in behavioral abnormalities. It is worthy of note, however, that although both researchers are working in the area of autonomic balance and behavior and both are well published (for example, Gellhorn, 1943; 1957; 1964; 1967; Gellhorn and Loofbourrow, 1963), neither seems cognizant of

the other's work. Rennie and Howard (1942) and Portis (1950) report a relationship between hyperinsulinism and psychoneuroses. Also, Rubin (1962) used pupillary responses as a measure of PNS (constriction) and SNS (dilation) activity and found that psychotics were either PNS or SNS dominant, again supporting Wenger and Cullen's (1972) findings.

Persistence of red dermographia. Two firm, slow, three-inch strokes with the rounded tip of a 22-mm instrument are made on the bicep of the left arm to form an X. Persistence of the visual evidence of the strokes is measured in minutes and typically varies between three and 30 minutes (Wenger and Ellington, 1943). During major sympathetic activation, blood is shunted away from peripheral areas to deep within the muscles. This decrease in peripheral blood volume during stress has been demonstrated by Bloom and Trautt (1977). SNS-dominant individuals should then have a short dermographic response, since they have a reduced peripheral blood supply. The reported scores for this test were markedly skewed; raw scores ranged from 1 to 45 while the mean was 10.17 (Wenger and Ellington, 1943). Nor does this test add much to the $\bar{A}$ defining equation as it has a beta weight of only .1. Finally, there exists no body of research to validate this measure. Due to these considerations, persistence of red dermographia was not used in the present study.

Salivary output. A subject is asked to swallow all saliva. A simple suction device is then inserted in the mouth, and the subject is asked to produce saliva as rapidly as possible and to allow it to be sucked from the mouth by the device. Adult subjects are given a three-minute collection period and preadolescents a five-minute period.

Salivary output is measured to the nearest .1-cc. Hafner (1974) reports that the salivary glands are controlled almost entirely by the PNS. Therefore, PNS-dominant individuals should produce more saliva than SNS-dominant individuals. This test also adds little to the $\bar{A}$ defining equation and may be offensive to some subjects. For these reasons, it was not used in the present study.

Heart period. Heart period is scored in milliseconds as the mean of four 10-beat samples (Wenger and Cullen, 1972). In the present study, heart period was the average interbeat interval over 110 seconds. Sternbach (1966) indicates that short periods indicate SNS activity while longer periods result from the decelerating influence of the vagus nerve, the major nerve in the PNS.

Wenger, Clemens, Darsie, Engel, Estress, and Sonnenschien (1960) found that epinephrine (SNS transmitter) injection did increase HR, and Epstein, Robinson, Kahler, and Braunwald (1965) conversely found that injection of a beta-SNS inhibitor (propranolol) decreased HR, as did Obrist, Gaebelian, Teller, Langer, Grignolo, Light, and McCubbin (1978). Using the same drug, Sonnenblick, Braunwald, Williams, and Glick (1965) found a slight decrease in heart rate during rest, while atropine, a PNS inhibitor, resulted in increased HR.

Obrist, et al. (1978) found increased HR to occur during a cold press test and a stressful (pornographic) film. Obrist, Lawler, Howard, Smithson, Martin, and Manning (1974), however, discuss the dual innervation of the heart but suggest that "vagal influences are not necessarily synergistic with sympathetic effects" (p.425). Obrist, Webb, Sutterer, and Howard (1970, p.570) discuss findings of "heart rate

reflecting primarily vagal effects and contractile properties reflecting primarily sympathetic effects."

Palmar SC. In the original battery standard-size electrodes were placed on the thenar and hypothenar surfaces of the right hand. In the present study, electrodes were placed on the pads of the middle fingers of the right hand since these surfaces yield more sensitive and stable measures of SC (personal communications with Dr. E. Katkin on May 18, 1979 and Dr. M. G. H. Coles on July 20, 1979). Subjects are seated and remain quiet. Two measurements, each of one-minute duration, are made. The sweat glands are controlled by SNS activity (Richter, 1927), and increased SC reflects SNS dominance (Sternbach, 1966; Lazarus and Opton, 1966; Kallman, 1975; Coles, Herzberger, Sperber, and Goetz, 1975).

Volar SC. The procedure is the same as for palmar SC, but subjects are in a reclined position with electrodes placed on the volar surfaces of the forearms just above the wrists, and two additional measurements are made. The lowest SC of the four is a subject's score on this test. Again, since no research body exists to validate the use of volar SC and since it has a low beta weight in the $\bar{A}$ defining equation (Wenger and Ellington, 1943), it was not used in the present study.

Respiration period. The mean respiration period in seconds from four samples of 10 complete respiratory cycles is the score for this test. In the present study, the reciprocal of the dominant respiratory frequency over 110 seconds was used as the score. Short respiration periods reflect SNS dominance (Wenger, 1942b).

Pulse pressure. Diastolic pressures are measured by auscultation at the brachial artery of a subject with cuff on the upper left arm. Six readings are taken over a 20-minute interval. The score is the mean diastolic reading, expressed in mm Hg, for the two lowest systolic pressures that duplicate each other. High scores reflect SNS dominance.

Porges's Autonomic Index

One two-minute sample of recordings of cardiac and respiratory activity provides the data for this measure. Porges (1976) examined the sensitivity of this technique of measuring vagal tone by comparing the weighted coherence estimates of seven normal and seven hyperactive (SNS-dominant) children. The hyperactives' C_w values were lower than the normal children's indicating SNS dominance. Secker (cited in Porges and Smith, in press) found that with normal children, behavioral inhibition (reflectiveness measured by the Matched Familiar Figures test) paralleled physiological inhibition (high C_w). However, Porges, Coles, Cheung, Drasgow, and Bohrer (1978) report that in normal subjects, although individual differences in HR-respiratory integration are stable, estimates of vagal tone are not (intrasession reliabilities of .60 to .65; intersession reliabilities with one week interval between measures, .59).

Visual Accommodation

The polarized vernier optometer is a new device for measuring the accommodative state of the eye. Subjects monocularly view two horizontal bars of light (the vernier) combined optically with either a visible stimulus scene (a checkerboard pattern) or darkness (the latter procedure yields a measure of the resting accommodation or dark focus,

the dioptric power of the eye in the absence of an external stimulus). This type of optometer was developed by Simonelli (1979) and is based on the Scheiner principle: when an object is viewed through a polarized filter one image is directed through the left half of the pupil while another image passes through the right half. When subjects view the vernier through a polarized filter, one half of the retinal image will shift relative to the other when the eye is focused infront of or beyond the vernier. The amount and direction of this shift indicate the direction of defocus.

The subject is presented brief exposures of the vernier pattern and asked to report the position of the left bar relative to the right bar. The experimenter then moves the vernier forward, if the subject perceives the left bar higher, or backward, if the left bar is reported lower. Eye accommodation can then be determined by a bracketing procedure until there is no perceived inequality in the horizontal position of the two bars.

The polarized vernier optometer is inexpensive, easy to use, and subjects are confident in their responses. Also, empirical comparison of estimates of dark focus using the polarized vernier with those using a laser optometer demonstrated the equivalence of these two optometers (Simonelli, 1979). The following were measured using the polarized vernier optometer:

Dark focus or resting accommodation. Dark focus has been previously defined as the dioptric power of the eye in the absence of an external stimulus. Originally the resting position was hypothesized to be at optical infinity. This has been demonstrated not to be the case

(Campbell and Primrose, 1953; Johnson, 1975). Although resting position varies among individuals, the mean is generally between 1 and 2 diopters (Otero, 1951, 1.12 to 1.24-D; Leibowitz and Owens, 1975, 1.7-D; Owens and Leibowitz, 1975, 1.98-D). Miller (1978a), however, reports a value of 2.76-D. Dark focus measures have been shown to be reliable over two or three days (Miller, 1978a, $r = +.95$) and over three weeks ($r = +.85$).

The resting state is a major determiner of accommodation to external stimuli. Owens and Leibowitz (1975) found correlations of the resting state with fixation state to a small luminous stimulus at near (2-D) and far (.25-D) distances to be +.92 and +.90, respectively. They concluded that the accommodative response to the light was determined primarily by the resting state and not the distance to the stimulus. Leibowitz and Owens (1975) and Leibowitz, Hennessy, and Owens (1975) came to the same conclusion from similar correlations of resting position with accommodation to stimuli of varying luminosity. Finally, Roscoe (1977), in a report of an experiment with opthalmic lenses, states that the eye does not "respond obediently to the accommodation distances called for by opthalmic lenses; the eye is lazy and reluctant to be drawn away from its intermediate resting position" (p.21).

Near point, far point. These represent the extremes of a subject's accommodative ability. The near point is the limit for positive accommodation and thus the theoretical maximum of PNS influence on eye accommodation. Conversely, the far point is the limit for negative accommodation and the point of maximum SNS influence. In support of this contention, Skeffington (1957) reports that as the difficulty of reading material increases, accommodation shifts outward

and blood pressure, respiration rate, and GSR increase. Also, Malmstrom, Randle, and Weber (1975) found "an overwhelming trend for the mean point of focus to shift and stay towards the visual far point during concurrent mental activity." Malmstrom (1978) reports similar findings and Randle, Roscoe, and Pettitt (in press) found that as the importance of flight decisions increased, during a simulated night landing task, the accommodative state shifted outward toward the visual far point. These shifts can be explained in terms of increased arousal resulting from mental activity, triggering an SNS response and hence an outward shift in accommodation. The near point was also measured using a RAF Near Point Rule, a rod-like device placed on the subject's cheekbones. It supports a lettered panel which is brought closer to the subject's eyes until blurring is reported. The point of initial blurring is defined as the near point of visual accommodation.

Variability. Alpern (1958) found that homatropine, a parasympatholytic drug, reliably reduced the variance of accommodative responses to test letters, thereby suggesting PNS influence on accommodative variability. Miller (1978a) found that, the higher the variability of a subject's resting accommodation, the greater the probability that dark focus was related to mood changes. Miller examined variability over three weeks, Alpern over one session. Since it is standard practice to use a bracketing procedure to determine dark focus, intrasession variability can be assessed by the range of dark focus estimates.

Performance

Individual differences in physiology seem to be reflected in behavioral differences (Wenger, 1947; Secker, cited in Porges and Smith, in press). Conversely, changes in behavior seem to effect physiology (Skeffington, 1957; Malmstrom, Randle, and Weber, 1975; Malmstrom, 1973; Randle, Roscoe, and Pettitt, in press). The relationships of tonic (baseline or trait) physiological levels to behavior and of phasic physiological shifts to concurrent changes in behavior are of considerable interest. A highly discriminating task is needed, however, to elicit these related responses.

The Delayed Digit Cancellation Task of the North battery requires a subject to cancel "visually presented digits by making the appropriate keyboard response corresponding to the digit previously shown in the sequence. The digits will be randomly chosen from the set 1, 2, 3, and 4. The keys are numbered 1, 2, 3, and 4 from left to right.... [A] correct response will correspond to one back in the sequence." (North, 1977, pp.106-107). The dependent measure on this task is the average latency for the final 20 correct responses. Other performance measures were also recorded (see the Results section). Performances on this task, varied widely, even among North's relatively homogeneous population (male flight students aged 18 to 26).

Digits were presented on a 22 x 22 cm plasma display panel of the Plato IV computer-based instructional system. This system generated all displays and scored and recorded the keyboard responses. Responses were given on a single left-hand configured keyboard with four keys: '1', '2', '3', and '4' linearly arranged and placed within easy reach of the

subject.

Subjects

The subjects of this experiment were 152 military trainees at Chanute Air Force Base, Illinois, who participated voluntarily. All individuals were 17 to 28 years old and were accepted regardless of size of refractive error or sex.

Procedure

Upon entering the laboratory, each subject was informed that the experiment involved obtaining several physiological measures and completing one paper-and-pencil test. Subjects were told that no pain or danger was involved at any time in the experiment. Subjects were then asked to complete the EPI. The time spent completing the EPI allowed subjects to acclimitize to the laboratory environment. Subjects then viewed the polarized vernier optometer. Dark-focus, near- and far-point accommodations were determined as previously discussed. Subjects were then physiologically tested individually:

A subject was seated in a chair, and a rubber bellows was placed securely around the subject's chest. The changes in pressure produced within the bellows by breathing movements were transduced into voltage levels by a Grass Model PT 5A volumetric pressure transducer. This signal was monitored by a Beckman 9806A A-C coupler set in a Beckman RB Dynagraph and a 2-minute recording was made with an Ampex SP 700 FM tape recorder. Respiration recording procedures were standardized by calibrating tonic breathing amplitude to a 2-cm pen deflection on the dynagraph. The sensitivity on the dynagraph remained constant for both the tonic and phasic portions of the experiment.

The subject's right arm and calves of both legs were exposed. The pads of the middle fingers and forearm surface of the right arm and the inside calves of both legs were swabbed with rubbing alcohol to remove surface oils and salts. Beckman standard-size Ag/AgCl electrodes were then attached to these surfaces with electrode collars. SC was recorded from the finger pads relative to a constant 0.5 volt DC reference imposed by a Beckman 9842 Galvanic Skin Response coupler (1 mm = 1 micromho). The electrodes to the pads were filled with K-Y surgical jelly.

The other three electrodes were filled with Beckman electrode paste. EKG was measured from active right forearm and left calf electrodes using a second Beckman 9806A A-C coupler. The right calf electrode served as a ground. Cardiac activity was standardized and recorded in the same manner as respiration. Subjects were instructed to avoid placing pressure on the electrodes since such pressure may create artifacts in recording (Edelberg, 1967). Intermittently during this procedure, BPs were measured six times from the left brachial artery.

Finally, subjects were given directions for the Delayed Digit Cancellation Task. They performed the task for four minutes. During the last two minutes, the latencies of correct responses were recorded. Immediately thereafter, dark focus, near- and far-point accommodations were measured as well as SC, BP, respiration period, and heart period. Any questions the subjects had concerning the experiment were answered at this time.

RESULTS

The physiological recordings of 27 subjects were eliminated from the data base due to the poor quality of these recordings. For the remaining 135 subjects, each individual's physiological scores were standardized and transformed to T-scores by the following formula:

$$T = 50 + 10(X - M)/SD$$

where X is a score on one physiological test, M the mean score on this test across all individuals, and SD the standard deviation of the scores of all individuals on this test. These scores were then entered into an R-factor analysis (applied to a matrix of correlations between variables, see Table 4). As can be seen from this table, only one correlation was statistically reliable. There was a tendency for subjects with greater skin conductance (SNS dominant) to have shorter heart periods (an SNS characteristic).

Table 4

Correlation Matrix of $\bar{A}$-Battery Tests

	HP	SC	RP
Heart Period (HP)			
Skin Conductance (SC)	-.20*		
Respiration Period (RP)	.05	.00	
Pulse Pressure (PP)	.04	.02	.03

* $p < .05$

The initial factors were extracted by a principal components factor analysis. This process was limited to two factors as suggested by Wenger (1941), see Table 5. Factor 1 has been defined by Wenger as the autonomic factor while Factor 2 was a skeletal muscular factor. The

loadings on Factor 1 are similar to those from a larger variable set presented by Wenger (1941). Also of interest is the direction of the loadings. PNS indicators (long heart and respiration periods) are positively loaded on Factor 1 while SNS indicators (high levels of skin conductance and pulse pressure) are are negatively loaded on Factor 1.

Table 5

Initial Factor Matrix

	Factor 1	Factor 2
Heart Period	.77684	.06049
Skin Conductance	-.76174	.16119
Respiration Period	.13674	.71223
Pulse Pressure	-.03082	.70084

The factors were then orthogonally rotated. Both the transformation matrix and the factor-estimate, or factor-score, matrix (listing of weights to estimate factors from variables) are presented in Table 6. $\bar{A}$ for each subject was determined in accordance with Wenger and Ellington (1943) as the sum of the products of the absolute value of the factor scores for heart period, skin conductance, respiration period, and pulse pressure times each subject's T score on the respective variable. The criterion for reliable factor loadings was set at +/-.30.

C_w was calculated by the following procedure: heart period was sampled from the data tape every 250 msec and was computed as the sum of each heart period that partially or wholly occupied the 250 msec interval. These computations were multiplied by the proportion of the

Table 6

Orthogonal Factor Matrices For Terminal Solution

	Transformation		Factor-estimate	
	Factor 1	Factor 2	Factor 1	Factor 2
Heart Period	.77079	.11408	.63994	.10335
Skin Conductance	-.77106	.10812	-.64233	.11263
Respiration Period	.08715	.71999	.06545	.69897
Pulse Period	-.07922	.69703	-.07270	.67828

interval in which the heart period was represented. Respiration amplitude was also sampled from the data tape every 250 msec.

The time series for heart period and respiration amplitude were then prestationed by removing linear trends and the mean (Porges, Bohrer, Keren, Cheung, Drasgow, and McCabe, 1979). The data were cross-spectrally analyzed and a weighted coherence coefficient calculated from the formula previously given (see the C_w section in the introduction).

A Pearson product-moment correlation matrix based on each individual's scores on $\bar{A}$ and C_w, the I/E scale of the EPI, as well as his or her mean dark focus over three trials, standard deviation in dark focus measures, and near and far points formed the data for the matrix presented in Table 7. Correlations were considered reliable at the .05 confidence level if they exceeded .158 (Child, 1970).

Reliable correlations existed between $\bar{A}$ and several other measures. $\bar{A}$ and C_w were positively correlated (r=.20) yielding

consensual support. $\bar{A}$ was negatively correlated with neuroticism (r=-.23) suggesting tne SNS-dominant individuals tend to be more neurotic tnan PNS-dominant individuals. $\bar{A}$ was also negatively correlated with both dark focus (r=-.21) and far point (r=-.18) indicating that PNS-dominant individuals have farther dark focuses and far points (SNS characteristics). However, C_w was positively correlated with near point (r=.18) implying that PNS-dominant individuals have nearer near points. This last finding supports Randles's hypothesis while those of $\bar{A}$ with dark focus and far point are contradictory to it.

Table 7

Correlation Matrix of Baseline Psychological and Personality Measures

	$\bar{A}$	C_w	I/E	N	DF	DFR	NP
$\bar{A}$							
C_w	.20*						
I/E	.10	.05					
Neuroticism (N)	-.23*	-.07	-.12				
Mean Dark Focus (DF)	-.21*	-.15	.03	.23*			
Dark-Focus Range (DFR)	-.01	-.06	-.16*	.03	.07		
Near Point (NP)	-.04	.18*	.00	-.05	.26**	-.10	
Far Point (FP)	-.18*	-.12	.06	.20*	.94**	-.03	.29**

* p < .05 ** p < .01

The eye accommodation measures were reliably intercorrelated: near point and far point, r=.29; dark focus and near point, r=.26; dark focus and far point, r=.94. Dark focus and far point were also related to neuroticism (r=.23, .20, respectively). More neurotic individuals

tended to have farther far points and dark focuses. Also, extraverted subjects had smaller ranges of dark focus (r=-.16) than more introverted subjects.

Following this, all measures were factor analyzed in the same manner as previously discussed. The initial factors (see Table 8) were orthogonly rotated. The transformation and factor-estimate matrices are given in Table 9. The number of terminal factors was limited by Kaiser's criterion that the latent roots for any one factor must sum to greater than one and therefore must not be uniquely attributable to a single variable (Child, 1970). However, the number of terminal factors was not allowed to exceed two in accordance with the rule of thumb put forth by Humphreys, Ilgen, McGrath, and Montanelli (1969) that the number of factors be limited to one fourth the number of variables.

Table 8

Initial Factor Matrix

	Factor 1	Factor 2
$\bar{A}$	-.41353	.42770
C_w	-.24182	.52311
I/E of EPI	-.02342	.49173
N of EPI	.39151	-.42227
Mean Dark Focus	.93924	.11911
Dark-Focus Range	.03430	-.44570
Near Point	.36433	.54607
Far Point	.92841	.19891

Table 9

Transformation and Factor-estimate Matrices For Terminal Solution

	Transformation		Factor-estimate	
	Factor 1	Factor 2	Factor 1	Factor 2
$\bar{A}$	-.26817	.53105	-.08583	.34039
C_w	.07590	.57128	.00650	.38172
I/E of EPI	.12340	.47602	.04224	.33213
N of EPI	.24875	-.51934	.07766	-.33387
Mean Dark Focus	.93234	-.16405	.42142	-.04341
Dark-Focus Range	-.09930	-.43584	-.07807	-.30273
Near Point	.50982	.41354	.26728	.31764
Far Point	.94564	.08522	.43341	.01140

Factor 1 is clearly a visual factor since it is dominated by dark focus and far point. However, since the two other visual measures (range of dark focus and near point) are not reliably loaded on this factor in the terminal solution, this factor is more specific than visual accommodation. It seems to reflect the outward mechanisms of accommodation. Factor 2, on the other nand, relates the the remaining six variables. For reasons discussed in the subsequent section, Factor 2 will be termed a continuity factor.

Changes in physiology related to the performance of the Delayed Digit Cancellation Task were assessed using several two-way analyses of variance. The first factor, session, was a repeated measures factor. Since the differences between tne measures taken before and after the task may nave been due to the task or to the passage of time, 34

subjects were used as controls against the latter case. These subjects rested for four minutes in lieu of performing the delayed digit cancellation task. Treatment: task or rest, constituted factor two. Anovas were calculated for the following variables: SC, heart period, respiration period, C_w, systolic (SBP) and diastolic (DBP) blood pressures, dark focus, relative dark focus (dark focus - far point), near, and far points, visual amplitude (near point - far point), heart rate variability (natural log of heart period variance), and vagal tone as shown in Table 10 and Figures 1 to 9.

Perusal of Table 10 yields the following conclusion: performance of the Delayed Digit Cancellation Task caused a shift in the SNS direction for the majority of variables (skin conductance, C_w, diastolic blood pressure, relative dark focus, visual amplitude, and near point). Additionally for several variables (skin conductance, heart period, and respiration period) there were SNS shifts for task subjects and PNS shifts for the subjects who rested. For two additional variables (dark focus and far point), this interaction approached reliability. Only systolic blood pressure and vagal tone exhibited a contrary effect, although even here the task subjects' post-treatment levels exceed those of the controls. Finally, three variables showed no reliable differences due to group or session (dark focus, far point, and heart rate variability).

Table 10

Two Way Analyses of Variance

Skin Conductance

Source	SS	DF	MS	F	P
Subjects (A)	7025.86	106	66.28		
Group (B)	24.30	1	24.30	.3666	.54615
Session (C)	135.38	1	135.38	8.5869	.00415
B x C	117.00	1	117.00	7.4214	.00754
A x C	1671.24	106	157.65		

Heart Period

Source	SS	DF	MS	F	P
Subjects (A)	2790220.70	100	27902.21		
Group (B)	100324.61	1	100324.61	3.5956	.06082
Session (C)	489.49	1	489.49	.1463	.70292
B x C	17971.94	1	17971.94	5.3710	.00251
A x C	334610.57	100	3346.11		

Respiration Period

Source	SS	DF	MS	F	P
Subjects (A)	241707480.00	100	2417074.80		
Group (B)	30114.62	1	30114.62	.0331	.85591
Session (C)	727575.93	1	727575.93	1.2265	.27074
B x C	2633606.10	1	2633606.10	4.4397	.03761
A x C	5931944.90	100	59319.45		

Table 10--Continued

Systolic Blood Pressure

Source	SS	DF	MS	F	P
Subjects (A)	19958.39	106	188.29		
Group (B)	149.44	1	149.44	.7937	.37500
Session (C)	289.35	1	289.35	6.9260	.00976
B x C	40.23	1	40.23	.9630	.32866
A x C	4428.41	106	41.78		

Diastolic Blood Pressure

Source	SS	DF	MS	F	P
Subjects (A)	5018.05	106	47.34		
Group (B)	199.40	1	199.40	4.2122	.04260
Session (C)	72.33	1	72.33	4.5028	.03617
B x C	17.25	1	17.25	1.0739	.30240
A x C	1702.91	106	16.07		

Dark Focus

Source	SS	DF	MS	F	P
Subjects (A)	495.08	103	4.81		
Group (B)	3.88	1	3.88	.8067	.37119
Session (C)	.04	1	.04	.1097	.74118
B x C	.47	1	.47	1.3233	.25266
A x C	36.32	103	.35		

Relative Dark Focus

Source	SS	DF	MS	F	P
Subjects (A)	55.08	106	.52		
Group (B)	.38	1	.38	.7366	.39260
Session (C)	.79	1	.79	5.0700	.02640
B x C	.57	1	.57	3.6723	.05800
A x C	16.48	106	.16		

Table 10--Continued

Near Point

Source	SS	DF	MS	F	P
Subjects (A)	2125.62	103	10.63		
Group (B)	22.08	1	22.08	1.0698	.30340
Session (C)	85.95	1	85.95	67.3286	.00000
B x C	.70	1	.70	.5475	.46100
A x C	131.49	103	1.28		

Far Point

Source	SS	DF	MS	F	P
Subjects (A)	440.93	102	4.32		
Group (B)	8.20	1	8.20	1.8978	.17130
Session (C)	.26	1	.26	1.0749	.30230
B x C	.00	1	.00	.0093	.92340
A x C	24.65	102	.24		

Visual Amplitude

Source	SS	DF	MS	F	P
Subjects (A)	2453.13	106	23.14		
Group (B)	51.94	1	51.94	2.2444	.13700
Session (C)	92.43	1	92.43	73.1150	.00000
B x C	.59	1	.59	.4650	.49680
A x C	134.01	106	1.26		

Table 10--Continued

C_w

Source	SS	DF	MS	F	P
Subjects (A)	6.25	86	.07		
Group (B)	.12	1	.12	1.6927	.19672
Session (C)	.27	1	.27	16.3312	.00012
B x C	.01	1	.01	.6893	.40853
A x C	1.42	86	.02		

Heart Rate Variability

Source	SS	DF	MS	F	P
Subjects (A)	558.39	106	5.27		
Group (B)	2.78	1	2.78	.5282	.46890
Session (C)	.62	1	.62	.2557	.61410
B x C	.38	1	.38	.1597	.69020
A x C	255.06	106	2.41		

Vagal Tone

Source	SS	DF	MS	F	P
Subjects (A)	1455.40	106	13.73		
Group (B)	9.60	1	9.60	.6993	.40490
Session (C)	9.78	1	9.78	3.6815	.05770
B x C	9.42	1	9.42	3.5475	.06230
A x C	281.57	106	2.66		

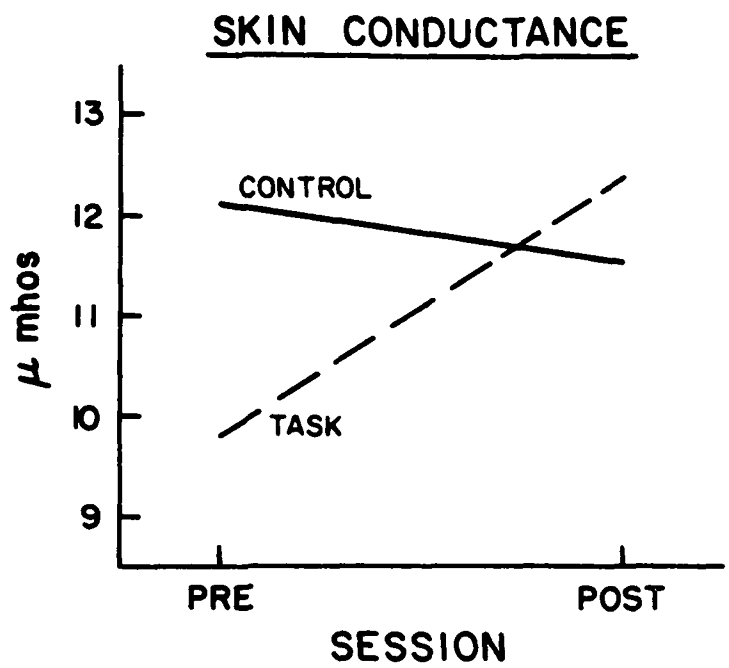

Figure 1. Skin conductance levels in μ mhos before and after task performance (for task subjects) or rest (for control subjects).

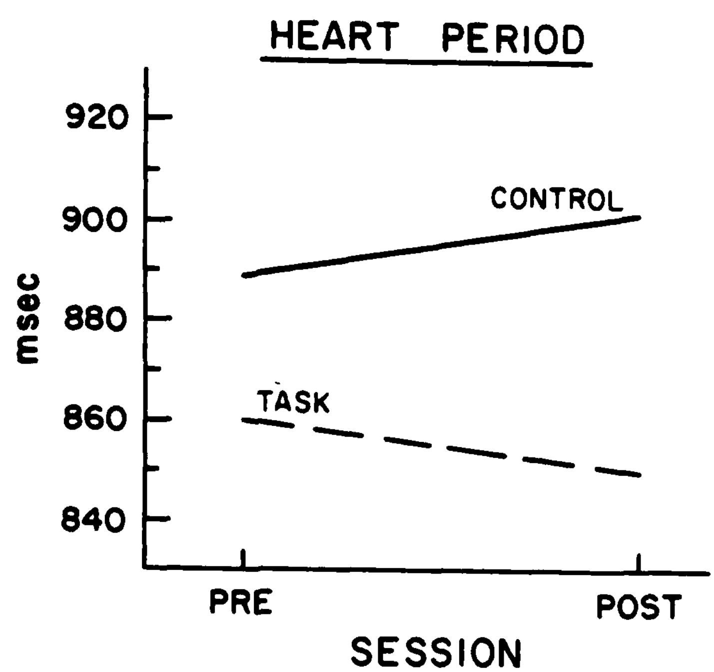

Figure 2. Heart period in msec before and after task performance (for task subjects) or rest (for control subjects).

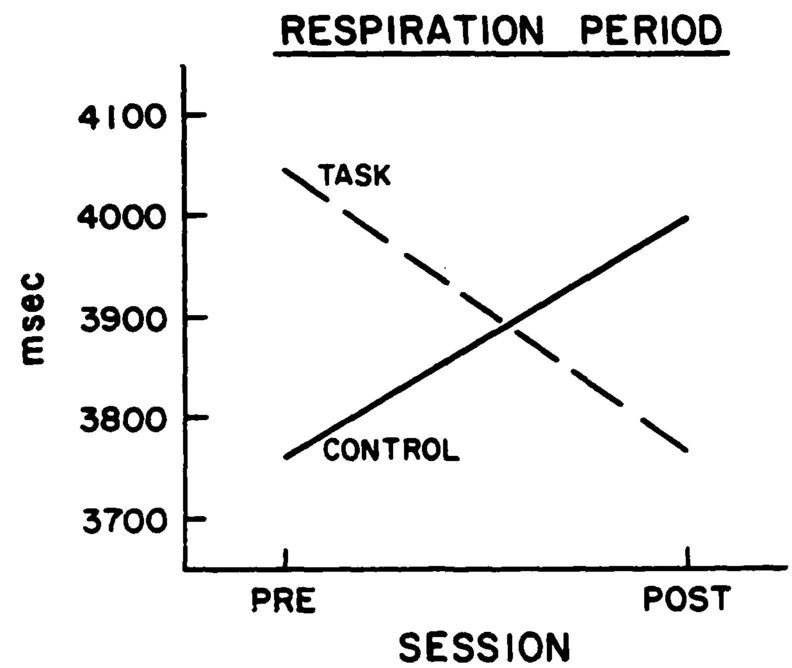

Figure 3. Respiration periods in msec before and after task performance (for task subjects) or rest (for control subjects).

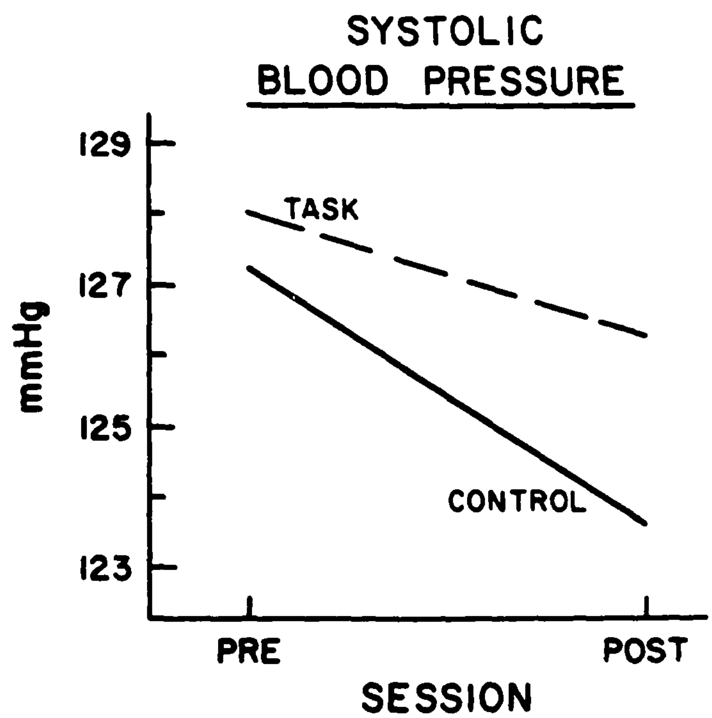

Figure 4. Systolic blood pressure in mm Hg before and after task performance (for task subjects) or rest (for control subjects).

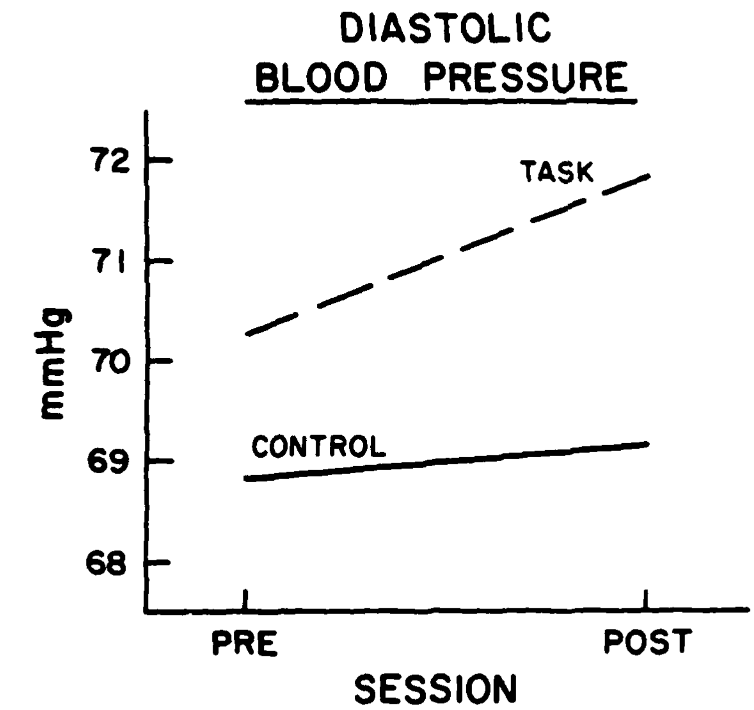

Figure 5. Diastolic blood pressure in mm Hg before and after task performance (for task subjects) or rest (for control subjects).

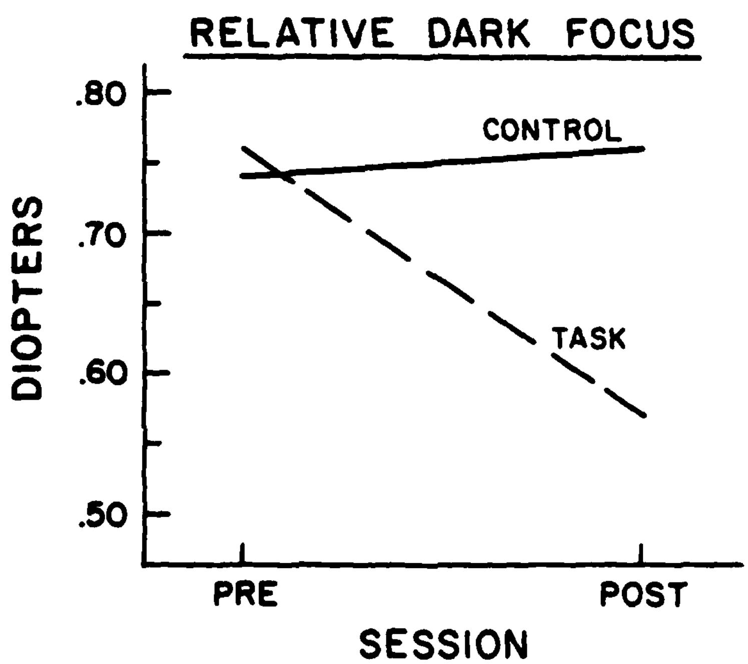

Figure 6. Relative dark focus in diopters before and after task performance (for task subjects) or rest (for control subjects).

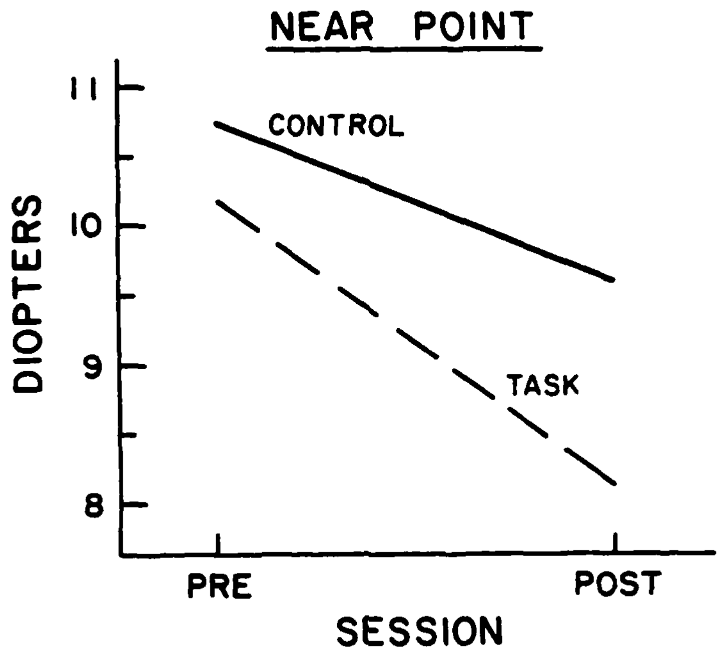

Figure 7. Near point in diopters before and after task performance (for task subjects) or rest (for control subjects).

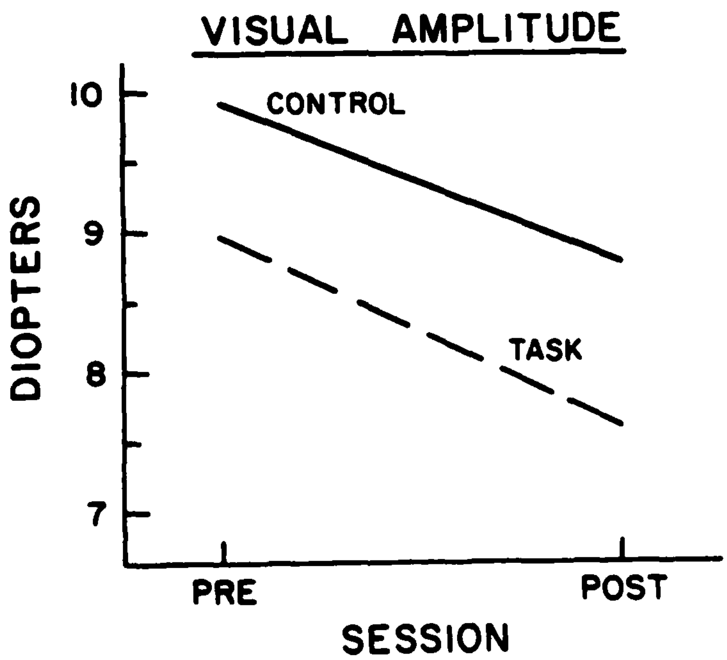

Figure 8. Visual amplitude in diopters before and after task performance (for task subjects) or rest (for control subjects).

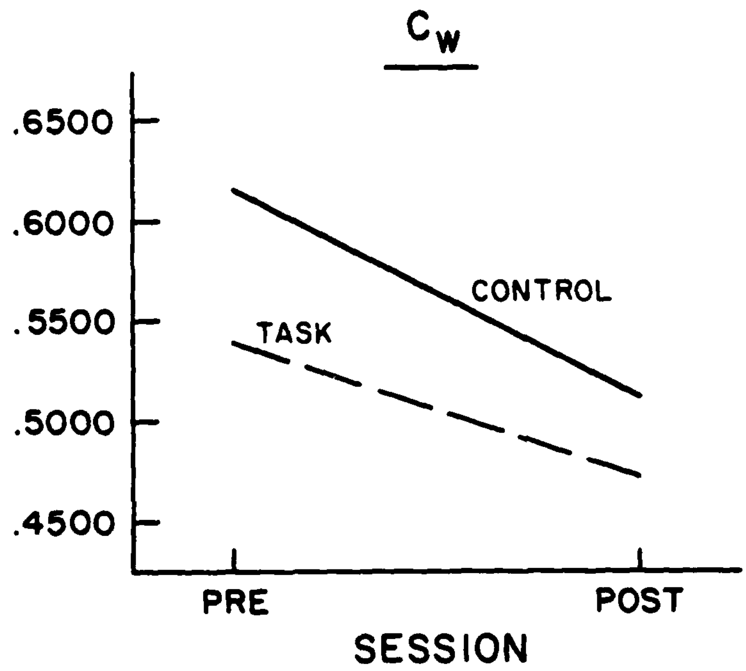

Figure 9. C_w before and after task performance (for task subjects) or rest (for control subjects).

Pearson product-moment correlation coefficients were also calculated for the means and standard deviations of the latencies for both correct and incorrect responses that occurred during the last two minutes of performance on the Delayed Digit Cancellation Task with each of the baseline measures (see Table 11). None of these measures adequately predict the average latency or variability of correct responses, but reliable correlations were found for both C_w and vagal tone with incorrect response latency and variability as predicted by Porges's hypothesis. Correlations of $\overline{A}$, C_w, and vagal tone with additional performance measures are listed in Table 11.

Table 11

Correlations of $\bar{A}$, C_w , and Vagal Tone

With Performance Estimates

	$\bar{A}$	C_w	V
Total Correct	-.17	.13	.22
Mean Latency Correct	.14	-.02	-.13
Standard Deviation of Latency Correct	-.02	-.16	-.20
Mean Log Latency Correct	.17	.01	-.10
Standard Deviation of Log Latency Correct	-.06	-.15	-.18
Total Incorrect	-.10	-.14	-.19
Latency Incorrect	-.03	-.35*	-.32*
Standard Deviation of Latency Incorrect	-.06	-.30*	-.36*
Mean Log Latency Incorrect	-.02	-.29*	-.13
Standard Deviation of Mean Log Latency Incorrect	.04	-.33*	.03
Percent Correct	-.09	.14	.20

* $p < .05$

N=74

In an attempt to explore further the possibility of predicting performance from baseline physiological measures, four stepwise discriminant analyses were performed involving performance variables that had not shown reliable correlations with baseline physiological variables. The criterion variable for each analysis was an estimate of performance during the last two minutes of the Delayed Digit Cancellation Task: number correct, percent correct, number incorrect, and mean log of the latencies of correct responses. Good versus poor performance was defined by median split. Predictor variables were dark

focus, dark focus range, near and far points, C_w, $\bar{A}$, vagal tone, heart rate variability, heart period, introversion-extraversion, and neuroticism. In each analysis the incidence of misclassification exceeded the arbitrary 25% criterion.

The performance criterion was then changed to compare only the extreme thirds. The four analyses were recalculated for this reduced data set. Two discriminant functions met the criterion for misclassification. One was based on the number correct: $-.36930C_w -.50264I/E + 1.07999\bar{A}$ [chi square = 13.444, $p < .001$; 80.6% correctly classified]; the other on latency for correct responses: 2.45617 dark focus range [chi square = 12.100, $p < .001$, 77.5% correctly classified]. In each case the more conservative Rao's V rather than Wilke's lambda was used as a criterion for decision making. These analyses suggest that individuals can be classified into performance categories by use of physiological and personality tests. In the first case good performers had higher I/E scores (more extraverted) and lower $\bar{A}$ scores (SNS dominant) but also higher C_w scores. In the second, they had narrower ranges of dark focus. Further examination of these relationships is needed.

Finally, an eta coefficient was calculated between the absolute value of standardized (z) scores of $\bar{A}$ with neuroticism scores. This was done to test Eysenck's hypothesis that subjects deviant in $\bar{A}$ in either direction (PNS- or SNS-dominant) would be more neurotic. The resulting correlation (r=.27) was not reliable.

DISCUSSION

Underwood (1975) suggests using "individual differences as a crucible in theory testing." Since individuals vary in $\bar{A}$, C_w, and degree of extraversion as well as in the four measures of EA (dark focus, dark-focus range, near point, and far point), the Eysenck and Randle hypotheses could be directly tested.

The Eysenck hypothesis would have been supported if there were reliable negative correlations between $\bar{A}$ or C_w and I/E scores, PNS-dominant individuals being more introverted. These correlations were unreliable. However, I/E was related to dark focus range. Introverted subjects tended to exhibit less consistent dark focus values. For full support of the Eysenck hypothesis there would have been a zero correlation of neuroticism with I/E. This correlation was indeed not reliably different from zero. However, neuroticism should have been positively correlated with deviation from mean $\bar{A}$; it was not, but neuroticism and $\bar{A}$ were correlated. SNS-dominant individuals tended to have higher neuroticism scores. This supports Wenger's (1947) contention that these individuals may be more emotional.

The Eysenck hypothesis that PNS-dominant individuals would also have high neuroticism scores may not have been adequately tested in the population used in the present study. The distribution of $\bar{A}$ scores was slightly skewed towards SNS dominance, and the sample of military trainees did not include the extremes found in the general population. Eysenck (1953) proposed that extraverts are SNS dominant. One of the common tests of this hypothesis is to correlate skin conductance and I/E scores. In the present study this correlation was not reliably different from zero. This finding coincides with those of Burdick

(1966), Purohit (1966), Revelle (1974), and Small (1974; 1976). Support for the Eysenck hypothesis from the present study was meager.

The Randle hypothesis that PNS-dominant individuals tend to be myopic and SNS-dominant individuals hyperopic would have been supported if and only if $\bar{A}$ were positively correlated with near point, dark focus, and far point and negatively correlated with dark focus range. $\bar{A}$ was reliably correlated with dark focus and far point but in the direction opposite to that proposed by Randle (cited in Roscoe and Benel, 1977). This suggests that it was the SNS-dominant individuals who were more myopic. The relationship between C_w and range of dark focus was both reliable and in the direction predicted by Randle. Furthermore, C_w was reliably correlated with near point indicating that, as Randle suggested from personal observation, PNS-dominant individuals have nearer near points.

Several considerations must be weighed in examining the relationship between autonomic balance and eye accommodation. In the present study both measures of autonomic activity were based on multiple and, in all but one case (pulse pressure), continuous measurements. Dark focus, near and far points, conversely, were estimated from single responses (although these were embedded in a bracketing procedure and pre- and post-treatment estimates were reliable). Also factor and cross-spectral analyses were used to define $\bar{A}$ and C_w. These are more powerful and certainly very different approaches to measurement from that used for eye accommodation. The low correlations may reflect this.

Also the measurement of eye accommodation constituted a discrimination task. As such and unlike the physiological measures, it

was intrusive and dependent on the subject's cooperation and understanding of the task. Individual differences in these may have added considerable variance to the measurement procedure. Also, since it was a task, it may have reflected more central processes than those proposed by Randle.

Most researchers have found myopia to be related to introversion. For example, Mull (1948) reported that myopes were more introverted than emmetropes. Also, Beedle and Young (1976) found myopes were more introverted than hypermetropes. This hypothesis would have been supported if there were strong, negative correlations between scores on the I/E scale of the EPI and dark focus and near and far points. Although the ranges of visual accommodation and I/E scores were broad, none of these correlations were reliable.

However, researchers who have found myopes to be introverted used tests other than the EPI to measure introversion. Mull (1948) used the Bernreuter Personality Inventory while Beedle (1974, cited in Young, Singer, and Foster, 1975) and Beedle and Young (1976) used the Omnibus Personality Inventory. Since the EPI scale measures did not yield results comparable to others found in the literature, it may be a poor measure of introversion. Conversely, it may measure sometning that tne other tests do not. As often occurs in psychology, constructs with the same name may not be equivalent.

Also, Mull (1948) and Beedle and Young (1976) used college students as subjects. These individuals tend to be more myopic than the population sampled in the present study (Simonelli, 1980). Indeed over half of Mull's subjects were myopes. The very different results

obtained with military recruits would be expected because they represent a population that differs in many ways from a population of college students.

Results from the first factor analysis were comparable to Wenger's findings and add conviction to the $\bar{A}$-battery's reliability. Factor 1 reflected peripheral autonomic functioning. The factor scores suggested that the factor was PNS defined: heart and respiration periods (long periods reflect PNS dominance) were positively weighted while skin conductance and pulse pressure (high scores on these indicate SNS dominance) were negatively weighted. The reliable correlation of skin conductance with heart period (subjects with greater skin conductance tend to have shorter heart periods) also supported a generalized autonomic factor reflecting the two antagonistic divisions of the autonomic system.

The second factor analysis yielded a somewhat clearer picture of physiological and personality relationships. Factor 1 was interpreted as an outward visual accommodation construct. It was defined by far point and dark focus. Though these measures are correlated, the correlation is not perfect. Dark focus is also correlated with near point. This supports the Liebowitz and Owens (1975) concept of dark focus as separate from far point and consequently supports the dual-innervation theory of accommodation.

Since the eye's resting position is not at infinity (where the far point was once assumed to be) but intermediate between the near and far points, it appears illogical to conceive of accommodation as an active process in one direction only, namely, inward from a relaxed

state at infinity. The "relaxed state" of dark focus is not at the far point but inward from it suggesting that dark focus is the balance of PNS (inward) and SNS (outward) forces.

Factor 2 was termed the continuity factor. Porges and Smith (in press) advance an assumption that there is continuity among various levels of functioning. Six variables loaded on this factor: $\bar{A}$, a measure of peripheral autonomic balance; C_w, a measure hypothesized to be sensitive to central autonomic balance; both behavioral measures (I/E and neuroticism); and two eye accommodation measures: dark focus range and near point. Each pair represents a different level of functioning and yet together they form one underlying dimension. Can these all be reflections of the same central mechanisms?

The Wenger (1947) hypothesis that individual differences in physiology are reflected in behavior would have been supported if reliable correlations existed between baseline physiological measures and performance on the Delayed Digit Cancellation Task. Such correlations with latency of correct responses were not found. Alternate measures of performance were then examined in relation to $\bar{A}$. None of the latency, error, and total correct measures could be predicted from $\bar{A}$. However, C_w, was reliably related to performance as estimated by the latency and variability of incorrect responses as was a measure of vagal tone proposed by Porges, et al.(1979). Vagal tone is the sum of the power density of heart rate at each frequency at which respiration normally occurs (see the Appendix).

Randle's hypothesis predicts that differential shifts in autonomic balance will be produced by the performance of cognitive tasks

(SNS shift) versus rest and relaxation (PNS shift). Reliable SNS shifts did occur after task performance. This supports Randle's contention and replicates Malmstrom's (1978) finding that task performance has an SNS effect. Application of these findings to the real world of aviation is as yet tentative but suggest the importance of future work in this area, particularly on the effects of elevated cockpit workload on pilots' approaches to landings.

What is needed for a thorough and critical test of the issues raised and studied here is continuous nonintrusive measures of visual accommodation and autonomic responses during performance of representative complex tasks. For this, sophisticated infrared optometers, polygraphs, techniques for removing the movement artifacts from tne physiological record, and fully grounded electronics systems are necessary. The cost would be high but the investigation is of sufficient theoretical and practical importance to warrant the undertaking.

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APPENDIX

Means and Standard Deviations For Baseline Measures

	Mean	Standard Deviation
Skin Conductance	10.42	3.30
Heart Period	869.87	127.66
Respiration Period	3903.45	1246.86
Systolic Blood Pressure	127.27	10.39
Diastolic Blood Pressure	69.63	5.36
Dark Focus	1.30	1.58
Dark Focus Range	.30	.29
Relative Dark Focus	.75	.61
Visual Amplitude	9.59	3.55
Near Point	10.40	3.30
Far Point	.55	1.41
C_w	.55	.20
Heart Rate Variability	7.75	1.82
$\bar{A}$	70.75	8.75
Vagal Tone	7.73	2.80

Additional analyses were calculated and are presented in the following tables. Due to the number of analyses peformed the reader should use caution in interpreting these tables. In each table the following abbrevations were used for more concise presentation:

I/E: Score on the Introversion-Extraversion scale of the EPI

N: Score on the Neuroticism scale of the EPI

SC: Level of skin conductance in micromhos

HP: Heart period in msecs

RP: Respiration period in msecs

SBP: Systolic blood pressure

DBP: Diastolic blood pressure

C_w: Weighted coherence

$\bar{A}$: Autonomic balance

HRV: Heart rate variability

V: Vagal tone

DF: Dark focus

DFR: Dark focus range

NP: Near point

FP: Far point

VA: Visual amplitude (near point - far point)

RDF: Relative dark focus (dark focus - far point)

Correlations Between Baseline Measures For All Subjects

	I/E	N	SC	HP	RP	SBP	DBP	C_w
N	-.11							
SC	.10	-.11						
HP	-.07	-.22	-.20					
RP	.03	-.10	.00	.05				
SBP	.06	-.04	.21	-.04	.05			
DBP	-.03	-.03	.01	-.01	-.03	.16		
C_w	.06	-.07	.08	.14	.41	.13	-.10	
$\bar{A}$	.01	-.23	.38	.61	.17	.09	.03	.21
HRV	-.07	-.06	-.04	.50	.30	.03	-.05	.20
V	.05	-.18	.03	.31	.19	.08	.00	.25
DF	.01	.20	-.01	-.22	.00	.04	.03	-.16
DFR	-.09	.07	.00	.00	-.13	-.06	.00	-.07
NP	.00	-.01	.01	-.02	-.04	.09	.03	.17
FP	.05	.18	.07	-.27	.06	.11	.05	-.13
VA	-.04	-.08	-.07	.09	-.03	.03	.02	.21
RDF	-.09	.09	-.19	.06	-.15	-.14	-.01	-.12

Table continued

	$\bar{X}$	HRV	V	DF	DFR	NP	FP	VA
HRV	.55							
V	.38	.68						
DF	-.21	-.09	-.12					
DFR	-.08	-.01	-.07	.10				
NP	-.20	-.16	-.11	.24	-.07			
FP	-.19	-.08	-.09	.94	-.02	.28		
VA	-.15	-.03	-.03	-.19	-.10	.90	-.16	
RDF	-.16	.01	.07	.44	.31	-.02	.09	-.05

N=152

Correlations Between Baseline Measures For Task Subjects

	I/E	N	SC	HP	RP	SBP	DBP	C_w
N	.03							
SC	.10	-.19						
HP	-.20	-.31	-.19					
RP	-.02	-.15	.14	.12				
SBP	.01	.09	.22	-.13	.03			
DBP	-.09	.02	.04	-.06	.00	.07		
C_w	.00	-.12	.15	.19	.56	.20	-.07	
$\bar{A}$	-.02	-.29	.29	.58	.31	-.06	.03	.26
HRV	-.13	-.07	-.02	.61	.38	-.07	-.04	.29
V	-.11	-.20	-.03	.56	.28	-.02	-.12	.48
DF	.02	.32	.06	-.22	-.01	.11	.01	-.07
DFR	-.13	.09	-.09	.02	-.20	-.02	.03	-.18
NP	.02	-.03	.09	-.02	-.01	.23	.03	.24
FP	.02	.29	.15	-.29	.08	.16	.06	-.03
VA	-.06	-.13	.05	.13	-.03	.11	.01	.22
RDF	-.02	.15	-.16	.10	-.23	-.10	-.07	-.14

Table continued

	$\bar{A}$	HRV	V	DF	DFR	NP	FP	VA
HRV	.59							
V	.48	.78						
DF	-.14	-.03	-.12					
DFR	-.10	-.01	-.15	.06				
NP	-.16	-.02	-.02	.26	-.10			
FP	-.10	-.04	-.15	.94	-.09	.31		
VA	-.10	-.02	.02	-.20	-.11	.89	.12	
RDF	-.17	.00	.02	.45	.37	-.01	-.17	-.11

N=74

Correlations Between Baseline Measures for Control Subjects

	I/E	N	SC	HP	RP	SBP	DBP	C_w
N	-.23							
SC	-.16	.21						
HP	.06	-.16	-.05					
RP	.32	-.04	-.11	-.26				
SBP	.10	-.06	.16	.27	-.03			
DBP	.22	-.28	-.15	.19	-.06	.35		
C_w	.17	.08	-.06	.07	.17	-.01	-.32	
$\bar{A}$	-.04	.02	.74	.63	-.19	.33	.07	.00
HRV	.41	-.06	-.15	.22	.39	.09	.00	.08
V	.42	-.14	.02	.17	.00	.13	.35	-.06
DF	.00	.35	-.11	.02	-.08	.10	.03	-.41
DFR	-.02	.19	.10	.09	.02	.06	.03	.09
NP	.02	.13	-.19	.17	.01	-.18	.05	.12
FP	.17	.39	-.02	-.01	-.01	.13	.05	-.42
VA	.15	-.29	-.40	.08	.17	-.12	.18	.29
RDF	-.27	-.14	-.34	.03	-.10	-.03	.05	.09

Table continued

	$\bar{A}$	HRV	V	DF	DFR	NP	FP	VA
HRV	.06							
V	.15	.29						
DF	-.09	.09	-.12					
DFR	.16	-.07	.05	.21				
NP	-.02	-.12	.09	.21	.01			
FP	-.03	.18	.05	.93	.12	.21		
VA	-.23	-.11	.02	-.17	-.04	.91	-.20	
RDF	-.26	-.16	.05	.40	.25	.05	.03	.19

N=34

Correlations Between Post-Task Measures

	SC	HP	RP	SBP	DBP	C_w	HRV	V	DF	DFR
HP	-.15									
RP	.17	.19								
SBP	-.08	-.02	.09							
DBP	.17	.04	-.07	-.02						
C_w	.11	.08	.40	.15	.15					
HRV	-.02	.57	.24	.14	.06	.02				
V	-.01	.53	.31	.17	.01	.37	.90			
DF	.14	-.16	.03	.03	-.24	.07	.00	.03		
DFR	.02	.08	.00	.08	.27	-.06	-.02	.04	-.11	
NP	.00	-.03	-.27	.01	-.11	.14	-.06	-.10	.32	-.18
FP	.20	-.18	.00	.04	-.17	.07	.00	.01	.95	-.20
VA	-.02	.06	-.26	-.04	.01	.15	-.11	-.14	-.16	-.16
RDF	-.20	.02	.08	-.06	-.25	-.07	.01	.08	.21	.30

	NP	FP	VA
FP	.35		
VA	.89	-.10	
RDF	-.14	-.10	-.19

N=74

$\bar{A}$ was not calculated post task since one measure requires sampling over 20 minutes.

Correlations Between Post Rest Measures

	SC	HP	RP	SBP	DBP	C_w	HRV	V	DF	DFR
HP	-.11									
RP	-.03	-.15								
SBP	-.16	.27	-.31							
DBP	-.01	.22	.08	.24						
C_w	-.05	.36	-.16	.01	-.22					
HRV	.00	.25	-.01	-.29	-.03	.41				
V	-.03	.28	-.13	.22	.10	.05	.96			
DF	.09	-.08	-.20	.19	.03	-.29	-.13	-.01		
DFR	-.11	.30	.05	.01	.05	-.34	.39	.41	-.17	
NP	-.27	.16	-.11	.25	.16	-.26	.06	.14	.20	.14
FP	.10	-.11	-.03	.23	-.02	-.24	-.13	.00	.95	-.21
VA	-.44	.14	.02	.13	.28	-.18	.22	.61	-.18	.22
RDF	-.15	.06	-.43	-.11	.22	-.23	.11	.04	.25	.11

	NP	FP	VA
FP	-.21		
VA	.92	-.28	
RDF	.04	-.07	.79

N=34

Reliability Estimates For Task Subjects

Pre- By Post-Measures

SC	.66
HP	.91
RP	.60
SBP	.74
DBP	.50
DF	.85
DFR	.43
NP	.88
FP	.88
C_w	.69
V	.75
HRV	.60
RDF	.54
VA	.89

N=74

Reliability Estimates For Control Subjects

Pre- By Post-Measures

SC	.66
HP	.54
RP	.65
SBP	.42
DBP	.46
DF	.96
DFR	.45
NP	.90
FP	.97
C_w	.50
V	.61
HRV	-.11
RDF	.61
VA	.91

N=34

Correlations Between Standardized $\bar{A}$ Scores

and Baseline Measures

	All Subjects	Task Subjects	Control Subjects
	$z\ \bar{A}$	$z\ \bar{A}$	$z\ \bar{A}$
I/E	.01	-.02	-.04
N	-.23	-.27	.02
SC	.38	.29	.74
HP	.60	.58	.63
RP	.17	.31	-.19
SBP	.09	-.06	.33
DBP	.03	.03	.07
C_w	.16	.22	.03
HRV	.55	.59	.06
V	.39	.48	.15
DF	-.21	-.14	-.09
DFR	-.08	-.10	.16
NP	-.20	-.16	-.02
FP	-.19	-.10	-.03
VA	-.14	-.10	-.23
RDF	-.16	-.17	-.26
	N=148	N=72	N=34

Correlations Between Standardized $\bar{X}$ Scores

and Performance Measures

total correct	-.17
mean latency correct	.14
standard deviation of above	-.02
mean log latency correct	.17
standard deviation of above	-.06
total incorrect	.09
mean latency incorrect	-.03
standard deviation of above	-.06
mean log latency incorrect	-.02
standard deviation of above	.04
percent correct	-.09

N=72

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